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**A PROJECT TO TRANSFER TECHNOLOGY FROM NASA
CENTERS IN SUPPORT OF INDUSTRIAL INNOVATION
IN THE MIDWEST**

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Sponsored by:

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National Aeronautics and Space Administration
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Introduction

In early 1981 the University of Kansas received a contract from the NASA Technology Utilization Division to initiate a technology transfer program utilizing graduate students in Mechanical Engineering. The objective of the program is to encourage industrial innovation in the Midwest through improved industry/University cooperation and the utilization of NASA technology. A related and important aspect of the program is the improvement of graduate engineering education through the involvement of students in the identification and accomplishment of technological objectives in cooperation with scientists at NASA centers and engineers in industry.

Background

A government study released in October 1979 suggested the expansion of programs promoting improved industry-University cooperation as a means of spurring industrial innovation and productivity. The study emphasized the need to foster the development of small high technology firms since they provide the majority of the innovations in the economy.

During the 1960's and 70's faculty and students of the University of Kansas Mechanical Engineering Department conducted a technology transfer program for small and medium sized firms based primarily on knowledge obtained from the scientific and technical literature utilizing computerized searching methods. This program was started in 1965 with modest first year support (\$15,000) from a grant to the University from the NASA office of University Affairs and has continued for nearly two decades with industry support. During the same period K.U. faculty members directed several projects wherein students performed research and applied advanced technology as they served internships at NASA centers as part of their graduate engineering programs.

The experiences of the investigators in the K.U. programs and that reported in the literature by others suggested that the most effective technology transfer process is one involving people with fundamental training in an area of technology and access to, or involvement in, state-of-the-art developments in the field. In early 1981 the Industrial Innovation Laboratory was established in the Mechanical Engineering Department and the first student appointed to gain additional experience with this approach.

Program Initiation

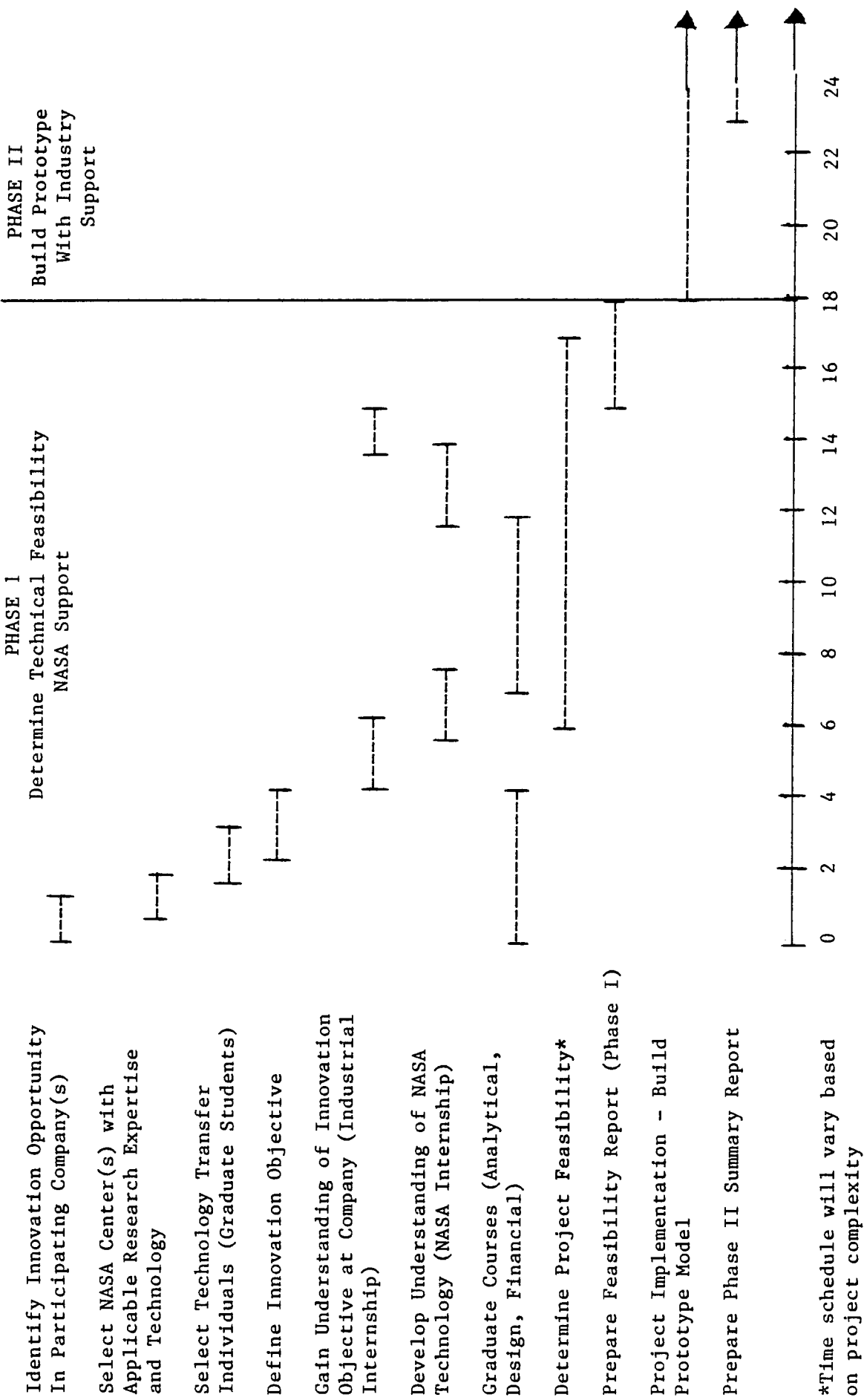
The receipt of the contract from the Technology Utilization Division to explore and develop a technology transfer model emphasizing an interactive mode utilizing graduate students as transfer agents between NASA laboratories and participating industrial firms was the crucial factor which made possible the founding of the Industrial Innovation Laboratory.

The original proposal to NASA provided a tentative schedule for accomplishment of an Innovation Project (Figure 1) which included:

- (1) the identification of an industrial objective,
- (2) the selection of a NASA Center(s) with the applicable expertise,
- (3) recruitment of the transfer agent(s) (graduate students).

It was assumed that the time schedule would vary based on project complexity and that early commitment of industry resources was essential to augment the University faculty commitment and NASA's support which was to provide access to the technology base and research assistant salary support (partial/interim) necessary for continuity.

NASA - University Innovation Project



Time Periods --- Months From Project Approval Date

Figure 1. Tentative Schedule* of Major Activities

Summary of Activity

Shortly after the appointment of the first graduate student to the NASA/University program the Industrial Innovation Laboratory initiated a project with Didde Graphics of Emporia to investigate the closed looped control of a printing press.

During the project definition stage the Innovation Laboratory Director and the graduate student spent two days at the Infrared Laboratory of the Johnson Space Center utilizing test facilities and equipment to evaluate methods of ink film thickness measurement. The cooperation given by the Center personnel was excellent and the tests conducted provided information which proved the inadvisability of an approach involving infrared technology. This determination eliminated the necessity to spend time and resources on an approach which had seemed promising. This experience quickly demonstrated a major benefit of the association with researchers at the NASA centers.

The economic recession (1981-83) effected the start up of the Innovation program almost immediately both positively and negatively. First, it reduced employment opportunities for students in private industry and thus made it easier to retain excellent well motivated research assistants for the K.U. graduate program. On the other hand, it reduced company sales and, therefore, made it more difficult to secure industrial support for innovation projects.

In early 1982 two additional students were appointed to the program and efforts began toward identifying innovation objectives with firms while concurrently introducing the students to NASA technology, (review of NASA Tech Briefs, "Spin Off" publication and current literature.) They were also exposed to the microprocessor hardware and software facilities becoming available to the Innovation Laboratory as a result of the equipment obtained by purchase and/or donation. (See related activities below.)

Three projects with well defined objectives were initiated in mid 1982. Two provided suitable thesis topics and received significant industrial funding inspite of the adverse economic climate. One of these projects, (Computer Vision Based Alignment Station) for DIT-MCO, a Kansas City, Kansas firm, received a funding authorization of \$23,000 and led within eight months to the involvement of two additional students in related robotic (short term/non-thesis) projects for the same company. The second resulted in a \$7,500 commitment to support the development of a microprocessor based control for a process chiller for Packer Plastics of Lawrence. The third, a short term (non-thesis) project to apply microprocessors to a quality control device for a small manufacturer in Kansas City was not funded by industry.

The challenges encountered in these several projects resulted in a decision to focus the technology transfer activities of the Innovation Laboratory on microprocessor or robotic type projects rather than any and all technologies which might relate to NASA's extensive knowledge base. NASA's long standing and continuing interest (and capability) in robotics, tele-operators and expert systems and industry's interest in developing improved processes and products using microprocessors, were major factors in the decision. It was also believed that the concentration of the Laboratory's efforts in this important and rapidly developing technology would result in more significant accomplishments than would a broader approach.

The time line of Innovation Laboratory activity (Figure 2) reveals that after the start-up year four or five projects have been running concurrently during each of the last three years. In the most recent period, industry support of individual projects has declined due to competition from a Computer Integrated Manufacturing Project sponsored by the Navy and the National Bureau of Standards. (See related activities below.) The

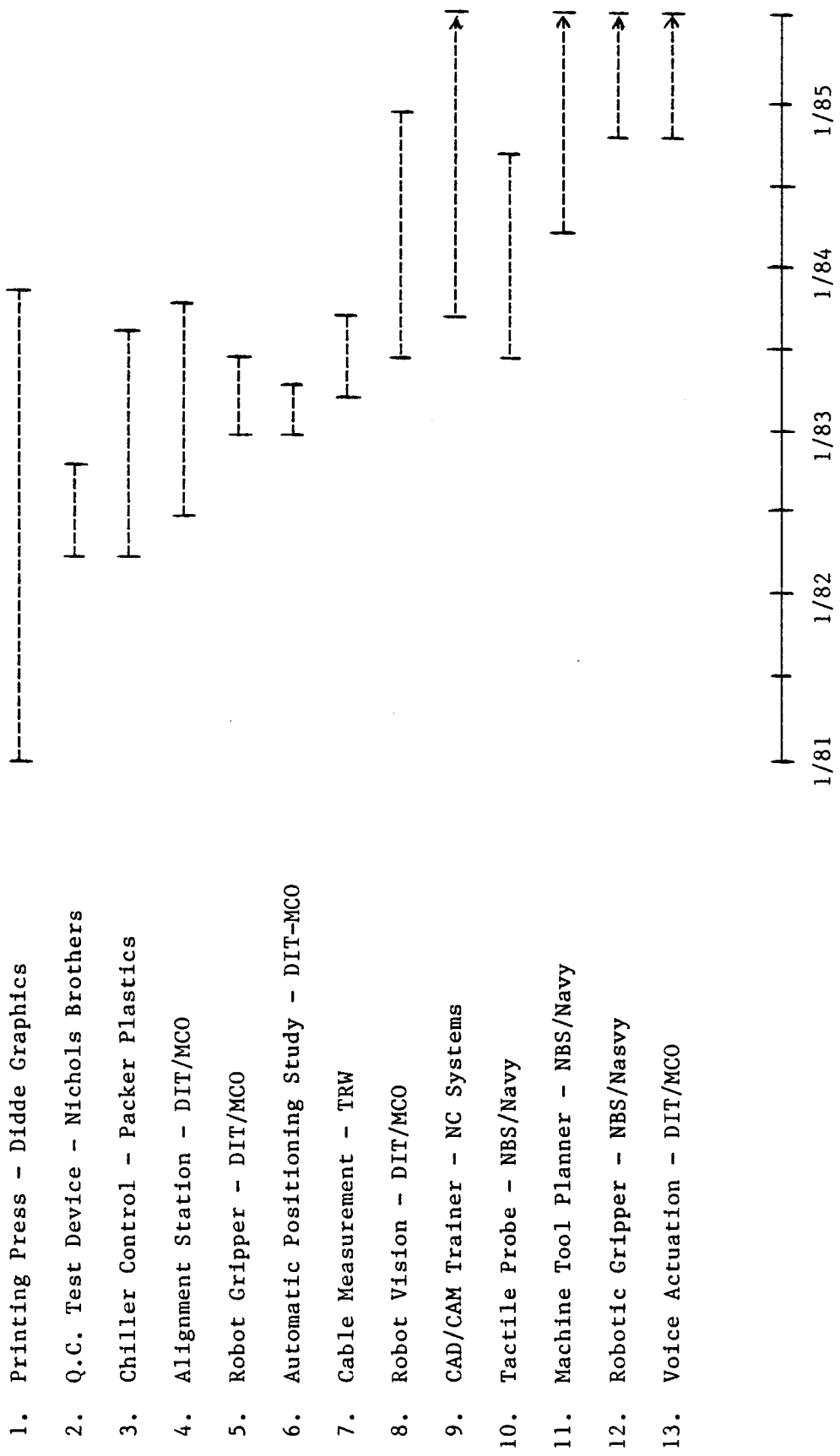


Figure (2) INNOVATION LABORATORY ACTIVITY
(January 1981 - December 1984)

decline in projects funded by industry is temporary and due to the shortage of qualified personnel to run both the NASA-Industry and Navy/NBS Projects concurrently without additional recruitment efforts.

Association with NASA Centers

During the initiation of the program the Principal Investigator visited scientists and engineers and technology utilization managers at Langley, Marshall, Ames and the Jet Propulsion Laboratory. These contacts have convinced the Principal Investigator that the area chosen is an excellent area for technology transfer activities between the University, NASA and industry since expert systems, artificial intelligence and robotics are important elements in NASA's mission and have been given high priority the next decade. The visitations have identified several areas of mutual interest and verified the willingness of researchers at NASA centers to have graduate students from the Industrial Innovation Laboratory work as interns in their facilities. One such arrangement was near fruition with the JPL Robotics Laboratory (Dr. Anatol Becjy), but it has been delayed due to the students acceptance of a position in industry. This is representative of the type of difficulty the program will encounter, indeed, because it is a successful program.

The training the students are obtaining in the program make them very desirable candidates for industrial opportunities and this points up the need to market the program to qualified American graduate students. It is our goal to maintain a creative environment at the University and through challenging associations with the NASA and industry motivate them to continue graduate study.

Related Activities (Education and Research)

The first Innovation Laboratory project (Ink Film Thickness Measurement) required knowledge of microprocessor based technology and access to state-

of-the-art hardware and software tools. A fortuitous unrestricted industry contribution of \$15,000 (Cities Service) matched by approximately \$10,000 from the University had enabled the Department to purchase a microprocessor Development System and initiate, on a trial basis, a course entitled "Introduction to Microprocessors" at about the same time microprocessor applications research was being initiated on the Didde Graphics project. Mike Carlyle, a Computer Scientist Graduate student, taught the course and was assigned one-quarter time on the NASA/University Program to provide essential technical support.

The initiation of the research and teaching programs in microprocessor based technology coupled with strong student interest and enthusiasm suggested proposals for additional laboratory equipment to National Science Foundation and the Intel Corporation of Santa Clara, California. Based on these proposals which were submitted in 1981 (and subsequent proposals) the Innovation Laboratory and the Mechanical Engineering Department have received major and continuing equipment support from Intel (the NSF proposal was not funded) which has resulted in the receipt of equipment and software with a retail value of approximately \$300,000. Proposals requesting additional equipment during 1985-86 and 1987 and totaling approximately \$300,000 were submitted to Intel in November 1984 and indications are that these will also be granted to support the research of the Innovation Laboratory and the educational program of the Department.

The successful operation of the Industrial Innovation Laboratory and the enhancement of the Mechanical Engineering curricula through the addition of the two microprocessor application courses (ME 608, Introduction to Microprocessors and ME 708, Microprocessor Applications in Mechanical Engineering) resulted in the Director of the Innovation Laboratory receiving a grant from the Navy Material Command and the National Bureau of Standards

for work with the Automated Manufacturing Research Facility (AMRF) at Gaithersburg, Maryland. This has provided funding of \$400,000 for a two year period, (April 1983 through March 1985) and the project is expected to continue at about \$250,000/year for several years.

The funding and the equipment available from this Navy/NBS effort have resulted in the establishment of a Computer Integrated Manufacturing (CIM) Laboratory directed by the principal investigator of the NASA/University Innovation Program. The CIM Laboratory has purchased approximately \$150,000 of state-of-the-art robotic and computer workstation equipment for artificial intelligence and robotic work. Seven students are working on this program on the application of microprocessors to improve fixturing and robotic devices as well as the development of automated process planning for a computer integrated manufacturing facility.

The CIM Laboratory is separate from the Industrial Innovation Laboratory, however, it is a direct result of the capability which the NASA/University program stimulated in the University of Kansas Mechanical Engineering Department. The objectives of the Navy/Bureau of Standards Project are compatible with the objectives of the NASA/University Industrial Innovation Program and a symbiotic relationship exists between them.

Results

A list of Industrial Innovation Laboratory projects is shown in Figure 3 and a summary of the objectives of each is attached as appendix A. These projects have been initiated with direct support from seven sponsors and eleven students have participated. Nine projects are complete and five of the nine thesis projects which were initiated have been completed.

An assessment of the benefits to industry shows that of the eight projects completed for industry: one (Didde Graphics) is still under study

Figure (3) INDUSTRIAL INNOVATION LABORATORY PROJECTS

(January 1981 - December 1984)

<u>Project</u>	<u>Sponsor</u>	<u>Project Engineer</u>	<u>Direct Project Support</u>
1. Measurement Ink Film Thickness (Thesis)	Didde Graphics Emporia, Kansas	Robert Wiedmaier MS, ME, 1984 Atchison, Kansas	\$20,000
2. Quality Control Test for Emergency Device	Nichols Brothers Kansas City Kansas	Mike Carlyle MS, CS, 1983 Lawrence, Kansas	---
3. Chiller Monitor and Controller (Thesis)	Packer Plastics Lawrence, Kansas	James Loughridge ME, ME 1983 Sioux City, Iowa	\$ 8,000
4. Computer Vision Alignment Station (Thesis)	DIT-MCO Kansas City Kansas	Joseph Majerle MS, ME, 1984 Prairie Village, Kansas	\$33,000
5. Robotic End Effector	DIT-MCO Kansas City Kansas	Michael Frain BS, ME 1984 Shawnee, Kansas	\$ 6,000
6. X-Y Positioning Table Study	DIT-MCO Kansas City Kansas	Andrew Weilert BS, ME, 1984 Roeland Park, Kansas	\$ 5,000
7. Oil Well Cable Measuring Device	TRW Lawrence, Kansas	Mike Carlyle Lawrence, Kansas	\$ 7,000

Figure (3) (Continued) INDUSTRIAL INNOVATION LABORATORY PROJECTS

<u>Project</u>	<u>Sponsor</u>	<u>Project Engineer</u>	<u>Direct Project Support</u>
8. Robotic Vision System (Thesis)	DIT-MCO Kansas City Kansas	Andrew Weillert MS, ME, 1984 Roeland Park, Kansas	\$31,000
9. Development of a Tactile Probe for a CNC Milling Machine (Thesis)	NBS/Navy Gaithersburg Maryland	Tom O. Davidson BS, ME April 1982 MS, Kansas, 1984	NBS/Navy
10. Prototype Computer Integrated Manufacturing Trainer (Thesis) (In Progress)	NC Systems Pittsburg Kansas	Michael Frain BS, ME 1983 Shawnee, Kansas	\$13,000
11. Proto-Type Expert System Based Machine Tool Planner For CIM (Thesis) (In Progress)	NBS/Navy Gaithersburg Maryland	Keith Hummel BS, ME 1983 Topeka, Kansas	NBS/Navy
12. Intelligent Robotic End Effector (Thesis) (In Progress)	NBS/Navy Gaithersburg Maryland	John Majerle BS, ME 1984 Prairie Village, Kansas	NBS/Navy
13. Voice Actuated Robotic System for Industrial Application (Thesis) (In Progress)	DIT-MCO Kansas City Kansas	Lynn Novak BS, ME Univ. of Va., 1980 Charlottesville, Virginia	\$ 8,000
Total Direct Project Support - Industry			\$131,000

and requires additional work and evaluation. Three (Quality Control Test Device, Chiller Control, Cable Measurement) are being utilized in industry and all contribute toward improved productivity. Four have provided information for feasibility studies for new or improved products or processes.

The Program has attracted several of the top Mechanical Engineering graduates and permitted them to remain at K.U. for graduate study. It has also attracted two top students from RPI and the University of Virginia and we expect this trend to continue with a student from the University of Wisconsin and one from Cambridge University expected to join the program in the near future.

NASA Investment

The NASA Technology Utilization grant has provided the very crucial infrastructure support for the program and has made possible the accomplishments summarized in Figure (4). \$114,000 of the \$148,000 authorized by NASA was expended through December 31, 1984 and provided 17% of the total support (\$685,000) to the program.

Industry Support

The program has been very successful in obtaining industry support (\$511,000 or 74% of the total). Equipment support totaling nearly \$400,000 has been provided through donation of microprocessor development systems, robotic systems and components to be used directly in the projects. A major portion of the equipment has been supplied by Intel Corporation of Santa Clara, California, which has donated equipment valued at over \$200,000 to support the program and the graduate and undergraduate educational program. In addition, Intel has supplied software with a retail value of approximately \$75,000.

Figure (4) SUMMARY OF INDUSTRIAL INNOVATION LABORATORY SUPPORT

	<u>Through 12/84</u>	<u>% of Total Support</u>
Laboratory Infrastructure Support - NASA (148K authorized)	\$114,000	17
Direct Project Support - Industry	\$131,000	19
Laboratory Equipment - Industry	\$380,000	55
Infrastructure Support - University	<u>\$ 60,000</u>	<u>9</u>
Total NASA/Industry Innovation Project Support	\$685,000	100%
<u>Related Funding</u>		
Navy/NBS For Computer Integrated Manufacturing Laboratory (Initiated in April 1983 based on Industrial Innovation Laboratory Capabilities)	\$400,000	

Conclusions

The pilot NASA/University Industrial Innovation Program has been an outstanding success based on its ability to:

1. attract top graduate students
2. procure industry support
3. stimulate industry/university cooperation leading to:
 - (a) enhanced university capability
 - (b) utilization of advanced technology by industry

A major difficulty in operating the program has been a shortage of qualified mechanical engineering professors with competence in microprocessor applications. This deficiency points up the need for the program since this technology is rapidly changing and the importance of its application will increase. It is extremely important that mechanical engineering graduates have training in the application of microprocessors.

It is believed that the program could have involved more students and additional companies if a decision had been made early to employ a full-time person to assist the principal investigator in both promotion of new project development and the supervision of the ongoing projects. The success of the first few projects led to additional projects at about the same time as that very activity led to the initiation of the Computer Integrated Manufacturing Laboratory.

The start-up of the CIM Laboratory ultimately resulted in a decreased number of students for the NASA Innovation project. Steps were taken to correct this in 1984. However, as the nation came out of the economic recession the increased employment opportunities for students made it more difficult to hold qualified graduates and the infrastructure personnel so essential to the development of a strong program.

These difficulties can be minimized through a slight increase in funding and a longer term commitment of NASA support to promote continuity and growth.

Appendix A

INDUSTRIAL INNOVATION LABORATORY

Project Summary

CRINC No. 5060 - Measurement of Ink Film Thickness - Sponsor: Didde Graphic, Emporia, Kansas; Project Engineer - Robert Wiedmaier.

The goal of the study was to demonstrate the feasibility of relating contact pressure to ink film thickness between the rollers on a printing press. The system was designed and built to monitor the pressure and the results obtained differed significantly from that predicted by analytical methods which were found in the literature. The sponsor was extremely pleased with project results and has proposed continuation of the work. Project personnel visited Johnson Center and JPL and utilized Tech Briefs during the project.

CRINC No. 5040-1 - Quality Control Test Device for Emergency Unit - Sponsor: Nichols Brothers, Kansas City, Kansas; Project Scientist - Mike Carlyle.

A Quality Control Test Device utilizing a microprocessor and an optical sensor was designed and constructed to eliminate operator checking of a products operation against specifications with an oilloscope. The device was built and demonstrated to the manufacturer and provided to him for further evaluation. Low sales of the product due to the economic recession delayed utilization of the quality control tester on the production line. A follow-up is required to determine the final usage and economic benefit.

CRINC No. 5730 - Chiller Monitor and Controller - Sponsor: Packer
Plastics, Lawrence, Kansas; Research Engineer - James Loughridge.

The project was implemented to reduce energy cost resulting from the operation of a chiller in the production of plastic cups and bowls on an injection molding machines. The project involved the application of a microcomputer, a flow sensor and two temperature sensors to control the chiller based on factory demand. The project was initiated in April 1982 and the controller was built and debugged by the student and installed by Packer personnel in the summer of 1983.

CRINC No. 5830 - Automatic Alignment Station - Sponsor: DIT-MCO, Kansas
City, Kansas; Research Engineer - Joe Majerle.

An Automatic Alignment Station was developed to accurately position hybrid integrated circuit substrates prior to their being tested for correct fabrication. The company's Project Engineer was very satisfied with the design and tests on the prototype system which accomplished the alignment automatically to the tolerances desired. The technology has been transferred and the Company is utilizing the information in the development of new automated work stations.

CRINC No. 6120 - Robotic End Effector - Sponsor: DIT-MCO, Kansas City,
Kansas; Project Engineer - Michael Frain.

DIT-MCO desired information on robotic end effectors which would permit the handling of substrates for integrated circuit type products. A literature search revealed no end effectors which would accomplish the purpose and the student proposed and evaluated several different designs experimentally. An end effector using vacuum and flow check valves proved satisfactory for the purpose and the company has taken steps to implement the design in one of its products.

CRINC No. 6140 - X-Y Positioning Table Study - Sponsor: DIT-MCO, Kansas City, Kansas; Project Engineer - Andrew Weilert. The sponsor requested a survey of the state-of-the-art of commercial positioning tables and controls. A literature and manufacturers survey was conducted with emphasis placed on tables combining high accuracy with low weight. Information from this study was to be used for the design of an automated circuit board test station. The information provided has been utilized by the company in its product development.

CRINC No. 6220 - Cable Measuring Device - Sponsor: TRW, Lawrence, Kansas; Project Scientist - Michael Carlyle.

TRW manufactures tertiary oil recovery pump cables. A device was required to accurately measure long lengths of the cables coming off of a production machine. A microprocessor based measuring system was designed and developed which resulted in the accurate measurement of varying lengths and diameters of cables. The device was installed by company personnel after fabrication by the Innovation Laboratory. Additional units have been fabricated by the company for other machinery based on this design.

CRINC No. 6380 - Robotic Vision System - Sponsor: DIT-MCO, Kansas City, Kansas; Project Engineer - Andrew Weilert.

A system was developed which integrated a robot with a computer vision system into an automated integrated circuit board test station. The system was implemented utilizing a low price solid state camera and an interface to an IBM Personal Computer. Pattern recognition techniques based on algorithms from NASA research aided in project definition and accomplishment. This work was completed in the summer of 1984 and led to the initiation of a follow-on project (5040-2).

CRINC No. 6450 - Prototype Cam Trainer - Sponsor: NC Systems, Pittsburgh, Kansas; Project Engineer, Michael Frain.

A very small entrepreneurial company, NC Systems, owned by a manufacturer's representative for CAD/CAM Workstations is developing a CAD/CAM Printer for vocational schools. A system is being designed which will utilize a microprocessor and related chips and the technology derived from the research of the Computer Integrated Manufacturing and Industrial Innovation Laboratories. A prototype system was developed and shown at a trade show in California in the Fall of 1983. A more sophisticated system was proposed based on this work and is currently under development. The project involves the design and fabrication of a microprocessor based system and the procurement of OEM Parts and extensive development of software.

CRINC No. 6630 - Tactile Probe - Sponsor: NBS/Navy, Washington, D. C.; Project Engineer, Tom Davidson.

A tactile probe was designed and developed for utilization with the K.U. Computer Integrated Manufacturing Workstation.

CRINC No. 6630 - Machine Tool Planner - Sponsor: NBS/Navy, Washington, D. C.; Project Engineer, Keith Hummel.

A machine tool planner for a part manufactured in a workstation of a Computer Integrated Manufacturing facility is being developed based on research conducted by the engineer at the Bureau of Standards and at the University of Kansas.

CRINC No. 6630 - Intelligent Robotic Gripper - Sponsor: NBS/Navy, Washington, D. C.; Project Engineer, John Majerle.

The work of the Industrial Innovation Laboratory and the Computer Integrated Manufacturing Laboratory and literature surveys revealed the inadequacies of robotic grippers currently available. Most are designed

for specific operation or for very limited tasks. A robotic gripper with local intelligence based on microprocessor technology is being developed as a thesis project. The project was initiated in December 1984.

CRINC No. 5040-1 - Voice Actuation of a Robot - Sponsor: DIT-MCO, Kansas City, Kansas; Project Engineer, Lynn Novak.

DIT-MCO seeks useful information concerning the applicability of voice actuated robotics to its product line. A literature and manufacturer's search of the available systems was conducted during the Fall of 1984 and resulted in the initiation of a project to couple an IBM PC equipped with a voice recognition board with an IBM 7535 robot. The robot was provided by DIT-MCO for utilization in this and other projects being conducted by the Industrial Innovation Laboratory. Scheduled completion of this thesis project is May 1985.